

Abstract

The collection of whole ceramic vessels at the Arizona State Museum (ASM) spans nearly 2000 years and encompasses all the major cultures and historical periods of the Southwestern United States. A survey including the examination of adhesives and residues was undertaken and has resulted in valuable information about the conservation and repair history of the vessels. By using visible examination, chemical spot testing, UV autofluorescence, and Fourier Transform Infrared Spectroscopy (FTIR) distinctive patterns of adhesive use have revealed how cultural groups, archaeologists, and conservators have used adhesives and repair techniques over time. The survey has also provided conservators with valuable insight into the efficacy of past repairs. Assessing the results will allow conservators to develop treatment strategies and prioritize conservation resources according to the needs of the collection. The opportunity to reconstruct early repair practices provides the museum conservators and curators with a valuable tool to evaluate, protect, and study this important collection.

Résumé

La collection de récipients en céramique du Arizona State Museum (ASM) couvre près de 2000 ans et englobe toutes les cultures principales et toutes les périodes historiques du sud-ouest des États-Unis. Une étude incluant un examen des adhésifs et des résidus a été entreprise et a fourni de précieuses informations sur l'histoire de la conservation-restauration des récipients. Au moyen d'un examen visuel, de tests microchimiques, de l'autofluorescence UV et de la spectroscopie infrarouge à transformée de Fourier (IRTF), des modèles distincts quant à l'usage d'adhésifs ont révélé comment les groupes culturels, les archéologues et les conservateurs-restaurateurs ont utilisé les adhésifs et les techniques de réparation au fil du temps. L'étude a aussi fourni aux conservateurs-restaurateurs des données précieuses sur l'efficacité des anciennes restaurations. L'évaluation des résultats permettra aux conservateurs-restaurateurs de mettre au point des stratégies de traitement et de prioriser les ressources en conservation-restauration selon les besoins de la collection. L'occasion de

Preliminary patterns of adhesive use in prehistoric and modern repairs of southwestern pottery in the United States

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Introduction

The Preservation Division at the Arizona State Museum (ASM), Tucson, Arizona, has undertaken a multifaceted project to upgrade the environmental storage conditions, treat, and relocate the Southwestern whole vessel collection. This project, initiated in 1999, is near completion and will see the entire collection surveyed, treated as necessary and moved into a new purpose-built storage area. The collection includes 20,000 vessels obtained through systematic archaeological excavation, ethnological study, donation and purchase.

Pottery vessel making in the Southwest is an ongoing tradition that spans about 2000 years (Haury p. 29). This pottery is known for its almost endless variations of texture, color, form and styles of decoration. Cultures throughout the American Southwest use a range of local clay materials to create black, red, white, and yellow wares. Ground stone and clays provide mineral pigments, colors and boiled plants provide the base for carbon black paints. Grinding paddles, carving tools, and polishing stones enable considerable diversity in both construction and finish. The designs seen in this collection seem to reinterpret traditional forms, create new styles, and even revive old ones.

An important aspect of the conservation survey has been the systematic identification of adhesives and residues found on the ceramics. The results from this effort provide valuable insight into the history of the collection and a useful planning tool for preservation and collections staff. In addition to assisting with a physical inventory, documentation confirmation, treatment scheduling and storage upgrades, the survey information has also enabled the identification of research projects (Shackle 2006), history of adhesive use (White and Odegaard 2008 a and b), fund raising (Save-A-Pot program) and the development of a new conservation tool (Frame, Segalman, White 2008).

The identification of adhesives and residues on cultural objects allows us to understand indigenous approaches to repair and their ingenious use of materials, as well as the development of a profile for repairs and treatments based on the materials used in the repair. A related literature survey provides known dates of the adhesive's introduction. By identifying the repair materials we can establish a profile of the collection's treatment history that includes both native and museum repairs. The resulting history will provide a valuable tool for conservators and researchers, as well as facilitate the protection and use of the collection.

Overview of the project, its scope and limitations

Repair materials range from modern museum conservation adhesives to original, native repairs in both archaeological and contemporary vessel collections. A significant number of the vessels in the Southwest pottery collection are

reconstituer les méthodes de
conservation anciennes fournies aux
conservateurs-restaurateurs et aux
conservateurs des musées un précieux
outil pour évaluer, protéger et étudier
une importante collection.

Esta colección de vasijas de
cerámica del Museo del Estado de
Arizona (ASM) abarca casi 2000 años de
historia, y comprende las culturas y
periodos históricos más importantes
del suroeste de los Estados Unidos.
Para esta colección se realizó un
estudio que incluía el análisis de
adhesivos y residuos, obteniéndose
valiosa información sobre la
historia de la conservación y
reparación/restauración de las vasijas.
Para realizar un análisis visual, análisis
químicos puntuales, auto fluorescencia
por rayos UV y Espectroscopia de
Transformada de Fourier por
Infrarrojo (FTIR), los patrones
característicos resultantes en el uso de
adhesivos han revelado cómo los
ceramistas culturales, arqueólogos y
restauradores han usado los adhesivos
y técnicas de reparación/restauración
a lo largo del tiempo. El estudio ha
proporcionado también a los
restauradores un valioso conocimiento
de la eficacia de las reparaciones/
restauraciones pasadas. La evaluación
de los resultados permitirá a los
restauradores desarrollar estrategias de
manejo y, según las necesidades de
conservación, priorizar los recursos
disponibles para la conservación. La
capacidad de reconstruir prácticas de
reparación/restauración pasadas ofrece
a conservadores y restauradores de
cerámica una valiosa herramienta para
proteger y estudiar esta
importante colección.

original adhesives from their period of use. Other vessels have subsequently been repaired during archaeological excavation or while at the museum. Our analysis of these materials includes UV and IR reflected light examination, chemical spot testing, FTIR spectroscopy, and other techniques that are recorded into a Microsoft Access® database.

The museum's catalog provides incomplete documentation about previous repairs or treatments for this collection that began over 100 years ago. Another conservation project that complements the condition survey is a comprehensive review of the conservation literature from 1900 to about 2005 that covers adhesives used to repair ceramics, glass, and stone. The review identifies over 20 different types of materials and over 400 variations based on chemical composition and physical form, carrier, and method of application. Our data allows us to determine patterns for the use of many types of adhesives on pottery and make comparisons to our collection.

Methodology

Adhesive identification is part of the overall collection condition survey that assesses condition and sets priorities for treatments. Substances noted as possible adhesives or coatings are identified by conservators using a variety of techniques. The methods generally used include visual identification with UV autofluorescence, chemical spot testing, and Fourier Transform Infrared Spectroscopy (FTIR). The combination and targeted use of these techniques have allowed conservators to quickly and systematically document the adhesive history of the collection.

Adhesive identification techniques

Visual examination and catalog documentation: Evidence of vessel repair can usually be verified by an experienced conservator's eye. Mended joins, shiny film, and discoloration provide clues to the condition and type of adhesives present. Excavation field notes, accession records, or catalog cards sometimes identify when and what was used to do a repair.

UV auto fluorescence: Some identification is performed using a portable UV lamp (Black Ray UVA lamp) and comparing auto fluorescence colors to known ASM reference materials. This technique is particularly effective for large assemblages of uniform vessel types. It is also useful for detecting multiple repair re-treatments that are only evident using UV radiation when multiple adhesives autofluoresce different colors.

Chemical spot testing: Many adhesive repairs can be easily tested with standard chemical spot tests reagents and procedures (Odegaard et al. 2005). The tests for cellulose nitrate, rosin, and protein are the most common, and provide a relatively quick analysis of adhesive samples. A basic protocol for this pottery project has been developed to facilitate identifications. One common example is the use of the diphenylamine-based spot test to detect adhesives known as cellulose nitrate, celluloid, or nitrocellulose. Cotton swabs dampened with acetone solvent are a fast and non-damaging way to remove a very small amount of adhesive during the survey. Swab tips can be kept for later testing in batches under conservation lab conditions. Adhesive samples that produce a negative reaction are then moved along for alternative testing procedures. Likewise, adhesives that have proved insoluble or resistant to acetone are identified by alternative testing methods.

FTIR: Adhesives that cannot be identified using the above methods are tested by Fourier Transform Infrared Spectroscopy (FTIR). This technique has been used primarily as a tool to confirm unusual or unexpected adhesives. The ASM lab has a Thermo Nicolet Avatar 360, microscope, and an attenuated total reflectance (ATR) with a diamond cell. Scanning is performed in the

the FTIR. Commercial libraries, the Infrared and Raman Users Group Spectral Database, and our own compiled library are used for con- references.

Testing procedure

The use of these techniques was determined by several factors including accuracy, and cost of the method. However the selection of an app- technique was always at the discretion of a professional conservator responsible for collecting accurate data while completing the proj- reasonable period of time. The large number of adhesive samples need a uniform testing system to ensure accurate testing and recording. With standard procedure, significant latitude was allowed to perform further for unique or unusual materials.

Results

The adhesives identified on the ASM pottery vessel collection are compared with commercially available products at the time of use and were recommended by archaeologists and museologists. A study of historic ad- was initiated to identify adhesives cited in literature for ceramic, glass and stabilization and compared those recommended for use with the de- mental history of commercial adhesive products. It serves as a refer- the adhesives used on the ASM vessel collection. To date, this database defines adhesive types on the basis of their chemical composition and p- form, includes over 900 entries. The preliminary results of the adhesive have been summarized below and in Tables 1-3 and Figure 1.

Table 1. Vessels that have failed and the adhesives used on them

Adhesive	Percentage of failed repairs
Cellulose Nitrate	97%
Animal Adhesive	2%
PVA	1%
Acryloid B-72	<1%
Pine Rosin	<1%

Table 2. Adhesives used throughout the collection

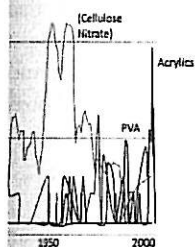
Adhesive	Incidence of use
Cellulose Nitrate	87%
Unidentified	3%
Acryloid B-72	3%
Animal Adhesive	2%
PVA	1%
Pine Rosin	1%

Table 3. Adhesives used in archeological and ethnographic repairs

Adhesive	Incidence of use
Pine Rosin	39%
Creosote Lac	20%
Unidentified Resin	14%
Clay/composite	9%
Animal Adhesive	8%
Mortar	5%
PVA	4%
Wax	1%

- Acryloid® B-72 and B-67 acrylic polymers began to appear in treatment reports around 1986. Since its introduction, B-72 has eclipsed other conservation adhesives and its current failure rate is below one per cent.
- Poly (vinyl acetate) or PVAC was used on slightly more than one per cent of the repaired vessels. PVAC (including several grades and mixtures) begins to appear in archaeological items in about 1984 and continues to appear in contemporary repairs to a small degree. Although the sample is small, it is notable that over 12 per cent of the PVAC-repaired ceramic vessels have since failed or become unstable. This is a significant failure and warrants further investigation on collections with more PVAC repairs.
- Cellulose Nitrate is the most widely used adhesive in this collection and is present on the majority of repaired vessels. It was used as early as 1908 at ASM, is the primary adhesive used by the 1920's and was used for 87 per cent of the museum and archaeological field repairs. This is typical of archaeological collections that were acquired and assembled in the last 75 years of the 20th century (Bulletin of the Museum of New Mexico 1938; Clearing House for Southwestern Museums, 1939). Its easy use is offset by the shortcomings in material properties. Strength decreases with age, brittleness increases with aging (Selwitz 1988). Currently, about 15 per cent of the cellulose nitrate repairs have failed, and four per cent are considered unstable. Of the vessels in the collection that have failed or are considered unstable 97 per cent of them were repaired with cellulose nitrate.
- Hide or animal based glues were commonly used adhesives for repairs prior to the introduction of cellulose nitrate. The usage of hide glue appears to extend to 1938 when it was used on a few archaeological and ethnographic vessels. Approximately five per cent of the identified glue repairs have failed and 19 per cent have been labelled unstable by conservators. Museums have long recognized the shortcomings of hide glue as a repair material (Orchard 1925).
- Creosote Lac is the resin exuded by the insect, *Tachardiella larreae*, on the leaves and stems of the creosote bush (*Larrea tridentata*). This material provided a strong, adhesive resin for peoples living in the southwest

ed in the Collection
Manufacture Year



ceramic vessels with
the collection, versus the
manufacture year of the
ethnic increments for

many centuries. The earliest example found during our survey was identified on an archaeological vessel from a cave site that had been radiocarbon dated to CE 1440–1640 (Shelly, Altschul 1989 p. 75). This adhesive continues to be used in contemporary Native American pottery as an adhesive and lid sealing compound. There are relatively few incidences of creosote lac in the collection, but they illustrate a long and continuous tradition of ceramic repair among some Native American groups, including the Tohono O'odham, Pima, Seri, Mohave, and Maricopa tribes (Sutton 1990, Felger and Moser 1985).

- Pine resins from several species in the pinaceae family including Pinion and Douglas are used as both an adhesive and as a sealing/waterproofing compound (Bohrer 1973). The Apache, Hopi, Navajo, Tarahumara, and Zuni people all have vessels with identified pine resin repairs or coatings. This material has a long and continuing use among contemporary potters, where it is often used as a surface coating on Navajo vessels.
- Gum from the mesquite tree (*Prosopis sp.*) was used to make an adhesive for repairs as well as paint for decorating pottery among the Tohono O'odham, Maricopa, and Pima people (Teiwes 1988, Kearney, Peebles 1951). Though reported in the literature, it has not been identified as an adhesive in the ASM pottery collections although is present as a painting material.

The results of the study have revealed patterns of material use that correlate to the traditions of the cultural groups and to the professional practices of the conservation community. Native American repair practices vary by group and region, but in the Southwestern United States, plant related products are the most common methods of repairing damaged vessels. The project has identified over 170 vessels (approximately one per cent of the collection) that retain residues from these original indigenous repairs. Modern conservation repairs, applied while the vessels were in the museum or archaeological excavation, have also been analyzed. Repair materials found in the collection include pine resins, creosote lac, animal protein adhesive, shellac, plasters and mortar, cellulose nitrate, polyvinyl acetate, and acrylic-based adhesives. The documentation of these repair materials and techniques will help the conservation staff reconstruct the treatment history of the collection. Systematic identification of these materials in combination with the condition survey will facilitate research on the collection and help prioritize conservation activities.

Mixtures and multiple re-treatments

Mixtures and multiple re-treatments are common in all repair traditions. Breaks may be repaired multiple times with different adhesives. Also, bulking agents and modifying compounds may be added to provide improved working properties. The identification of mixtures is significantly more complex than pure compounds. It is necessary to consider the limits of detection and the possibility of interactions among other components when evaluating the results of UV autofluorescence, chemical spot testing, and FTIR spectroscopy.

Many vessels in the collection have a complex mixture of adhesives bridging prehistoric and historic periods. Breaks may be repaired multiple times with different adhesives. In this example of an ethnographic repair (Figures 2 and 3) the relationships are relatively straightforward and readily visible with a UV lamp. Identification was performed with the FTIR and identified bitumen, with a later campaign of pine resin. A third compound without noticeable UV fluorescence was tentatively identified as a gum, although work is continuing to provide a more definitive identification.

Multiple adhesives used on the same vessel are found in only four per cent of the collection. This example of creosote lac used as a sealing compound on a vessel illustrates a difficulty in identifying complex mixtures (Figures 4–6).



a jar, 20th century.
—33–24



r UV autofluorescence
shown in Figure 2



Figure 4. Pima jar, 700–1050 CE.
Accession number E-2374

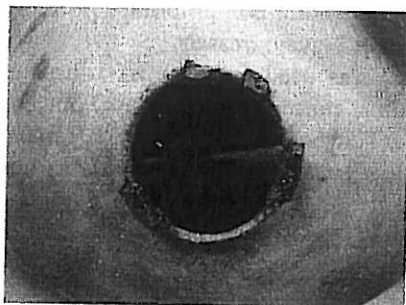


Figure 5. Detail of Pima jar shown in
Figure 4 (accession number E-2374)
showing the rim under visible illumination.
Adhesive residues are clearly visible

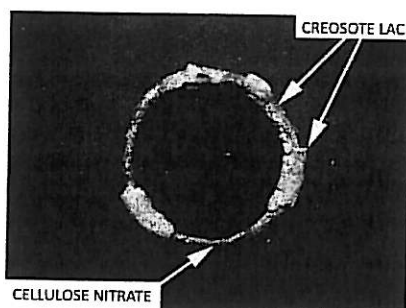


Figure 6. Detail of Pima jar shown in
Figure 4 (accession number E-2374), with
rim under UV illumination. Two distinct
adhesive residues were identified: creosote lac
and cellulose nitrate

completely coated the exterior surface. The only orange fluorescence remains, is in areas where the creosote lac was directly adhered to the ceramic and has since detached, exposing the original adhesive fluorescence. Examination with the UV lamp revealed the surface coating of cellulose nitrate. Interpreting and identifying multiple repair re-treatments is a challenge when attempting to reconstruct the repair history of any object.

Other repair techniques

Repair holes in the collection were specifically selected by curatorial staff for an item that was of interest and had been insufficiently documented in the ASM. Repair holes are a technique to mechanically secure cracked or broken vessels with ties. Holes were drilled on adjacent sides of a break and the two pieces were mechanically secured with a fiber or cord fastener. The incidence of repair holes on all vessels was noted as part of the conservation survey. Preliminary totals suggest that they are present on 1.2 per cent of the vessels (approximately 240 vessels) in the ASM. Figures 7 and 8 clarify the distribution of repair holes among Southwest cultures. The acquisition of this valuable data illustrates how a collection survey can augment curatorial records and benefit other groups within the museum.

Most of the repaired ASM pottery vessel collection was done to fill losses. Rather, the vessels were reconstructed using only the fragments available. A smaller but significant portion of the collection received at least some fills, and they appear to have benefited significantly.

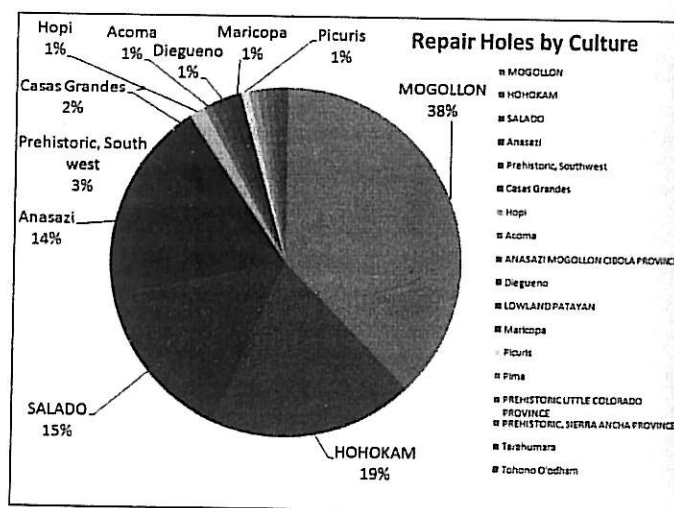


Figure 7. Distribution of vessels with repair holes (total $n \sim 240$ vessels), by culture

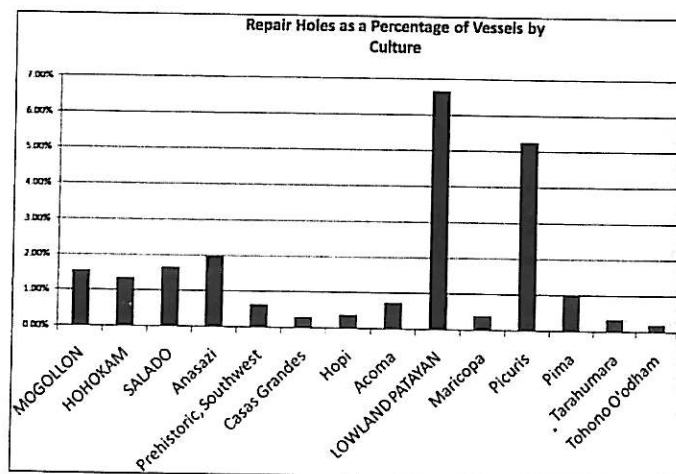


Figure 8. Percentage of vessels with repair holes by culture (calculated as: culture X vessels with repair holes/total number of vessels from culture X)

from the additional structural support. The failure rate of ceramic repairs drops by over 50 per cent when fills are incorporated within the vessel structure. The additional effort to provide fills imparts a measurable benefit to the collection and should be considered in order to prevent damage and prolong the life of treatments.

A limited number of ceramic vessels have supportive exterior lacing or ties used to support the vessel structure. Though generally noted on very large vessels, a range of plant fiber, rawhide, and modern iron wire materials have been recorded. These seem to be used to provide extra handling support to the structure, supplement adhesive repairs, or prevent structural damage.

Conclusion

This collection is actively used by researchers and is subject to significant handling, contributing to increased damage. The documentation of the collection's adhesives is a benefit for curators and conservators alike. Conservators benefit by gaining a better understanding of the materials used on the collection. Understanding the distribution of adhesive types, how they are aging, and how they function provides valuable guidance in developing preservation strategies for a large collection. The survey reveals how adhesives are used in the collection on an item level as well as the aging properties of repair techniques over time. For example, data from the survey suggest that repair failure has been a significant problem in this research collection. Insufficient records or earlier failures/repairs prevent truly accurate modeling of the past and likely future failure rates but general trends are illustrated. The uncertain longevity of cellulose nitrate suggests that a sustained campaign of reassembly may become necessary as these adhesives continue to age and a probable increasing failure rate will require substantial resources to address.

Curators and researchers benefit from the detailed, reliable information about residues and repairs in their collections. Sometimes this information can help link poorly documented items to an era of collecting, the activities of early collectors, or simply clarify the otherwise misleading appearance of surface or decorative areas on a vessel. Confident knowledge of this information helps curators understand the history of their objects and how materials, techniques and culture interrelate.

Cultural groups may gain greater understanding and depth to the object histories. During the Pottery Project, the conservation staff has conducted several consultation meetings regarding the study, condition, treatment, storage and exhibition recommendations of tribal members whose cultures are represented in the ASM collections. Information related to primary and secondary uses, storage and use strategies for food and water resources, as well as sentimental or ceremonial contexts are of interest and have provided guidance in the treatment and understanding of vessels and the context of their repairs.

The identification and correlation of adhesive and repair techniques to culture helps illustrate the cultural history of objects for curators and provides conservators with valuable information about collections. The cooperative gathering and sharing of information between curatorial and conservation staff benefits understanding and preservation of the collection. The systematic study of repair techniques as a continuation of object history adds further value to the objects in the collection.

This project has successfully identified conservation problems based on observed and quantifiable trends in adhesive use. The data has also resulted in a significant new resource that links conservation treatments to a continuous tradition of ceramic repair. By measuring how well or poorly previous treatments behave, we can better predict the collection needs and confidently identify effective strategies. This research affords the opportunity to look forward and backward to identify patterns in archaeological methods,

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References

- Bohrer, V L. 1973. Ethnobotany of Point of Pines Ruin, *Economic Botany*, 27, 2: 37.
- Felger, R, and Moser, M. 1985. *People of the Desert and Sea: Ethnobotany of the Indians*. The University of Arizona Press, Tucson.
- Frame, L, Segalman, I, White, C. Conductivity Probe Prototype: Measuring Soluble Content on Ancient Ceramics. *Western Association for Art Conservation* (January) 29(1), 12-14.
- Haury, E W, Reid, J J, and Doyel, D E. 1992. *Emil W. Haury's Prehistory of American Southwest*. Tucson: University of Arizona Press.
- Kearney, T, Peebles, K, et al, 1960. *Arizona Flora: Second Edition*. University of California, Berkeley.
- Odegaard, N, Carroll, S, Zimmt, W S. 2000. *Material characterization tests for objects of art and archaeology*. 2nd edition. London: Archetype Publications.
- Shackle, A. 2006. *The Study and Use of Cultural Repair Techniques in Archaeological and Ethnological Conservation*. Master's Thesis. University College London.
- Smith, B C. 1999. *Infrared spectral interpretation: a systematic approach*. Boca Raton: CRC Press.
- Sutton, M Q. 1990. Notes on creosote lac scale insect resin as a mastic and sealant in the southwest Great Basin. *Journal of California and Great Basin Anthropology* 262-268.
- Teiwes, H. 1988. The Art of Rupert Angea. *Maskerkey* 62(1), 3-11.
- White, C and Odegaard, N. 2008a. Prehistoric and Ethnographic Repair Techniques: Materials on Southwestern Native American Pottery. Unpublished Paper. Holding it all together, conference at British Museum, London. February 2008.
- White, C and Odegaard, N. 2008b. How a Conservation Survey Evaluated the Success of Ancient and Historic Repairs to Southwestern Pottery. Unpublished Paper. International Curation Standards: What's Working, What's Not. March 2008.
- Shelly, S and Altschul, J. 1989. *Paleoenvironments and Archaeology of the Mountain: Data Recovery in the Hart Mine and Cibola Quarry Areas, Pima County, Arizona*. Gray Literature Press: Tucson, Arizona.
- Procedure in archaeological field work and directions for treatment of specimens in museum and laboratory. 1938. Museum of New Mexico.
- Notes on Pottery Mending Techniques: Adhesives. (1939, September). Clearing House For Southwestern Museums, Central Office - Denver Art Museum, 47-48.
- Infrared and Raman Users Group (IRUG) Spectral Database - Edition 2000. Retrieved between September 2005 and November 2007, from <http://www.irug.org>